[redacted]

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES
3 4456 0361352 4

CENTRAL RESEARCH LIBRARY
DOCUMENT COLLECTION

ORNL-2665
C-85 - Reactors-Aircraft Nuclear Propulsion Systems

CENTRAL RESEARCH LIBRARY
DOCUMENT COLLECTION
LIBRARY LOAN COPY
DO NOT TRANSFER TO ANOTHER PERSON
If you wish someone else to see this document, send in name with document and the library will arrange a loan.

cy. 57A

DECLASSIFIED
CLASSIFICATION CHANGED TO: OAEC 5-6-70
BY: [illegible] 12-8-70

OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

PROGRAM 4700

DECEMBER 1958

[redacted]

OAK RIDGE NATIONAL LABORATORY
operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

[redacted]

[redacted]

[redacted]

C-85 Reactors - Aircraft
Nuclear Propulsion Systems

ORNL-2665

This document consists of 9 pages.
Copy 57 of 58, Series A.

Contract No. W-7405-eng-26

OAK RIDGE NATIONAL LABORATORY
STATUS AND PROGRESS REPORT
PROGRAM 4700

December 1958

Date Issued: JAN 7 1958

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee
Operated by
UNION CARBIDE CORPORATION
for the
U.S. ATOMIC ENERGY COMMISSION

[redacted]

MARTIN MARIETTA ENERGY SYSTEMS LIBRARIES

3 4456 0361352 4

[redacted]

OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

TABLE OF CONTENTS

	Page
PROGRAM 4700 - REACTOR DEVELOPMENT	3
AIRCRAFT NUCLEAR PROPULSION PROJECT	3
Tower Shielding Reactor II (TSR-II) Development and Fabrication	3
Bulk Shielding Facility (BSF) Experiments	4
Tower Shielding Facility (TSF) Experiments	5
Lid Tank Shielding Facility (LTSF) Experiments	5
Oxidation Studies of Columbium	6
Fabrication of Columbium Alloys	6
Corrosion Resistance of Type 316 Stainless Steel to Contaminated Lithium	7
Brazing Alloys for Service in Lithium	7
Yttrium Preparation	8
Creep Buckling of Shells with Double Curvature	8

Reports in this series issued during the past year:

December 1957	ORNL-2459
January 1958	ORNL-2472
February 1958	ORNL-2488
March 1958	ORNL-2507
April 1958	ORNL-2526
May 1958	ORNL-2547
June 1958	ORNL-2564
July 1958	ORNL-2580
August 1958	ORNL-2596
September 1958	ORNL-2624
October 1958	ORNL-2637
November 1958	ORNL-2646

[redacted]

[redacted]

OAK RIDGE NATIONAL LABORATORY

STATUS AND PROGRESS REPORT

December 1958

This monthly report covers those AEC activities which fall under program 4700, categories C-84 and C-85, classified SECRET. Some of the topics are reported every month, but the majority are reported bimonthly.

PROGRAM 4700 - REACTOR DEVELOPMENT

AIRCRAFT NUCLEAR PROPULSION PROJECT

Tower Shielding Reactor II (TSR-II) Development and Fabrication

Additional experiments were carried out with bare, water-moderated, critical arrangements of the first TSR-II core in order to determine a procedure for utilizing this core for low-power shielding experiments and to obtain data for designing a new core for high-power operation at the Tower Shielding Facility. A comparison of the thermal-neutron fluxes with the calculated fluxes showed excellent agreement in the internal reflector and core regions; however, the observed peak flux in the external water reflector was a factor of 2 higher than the calculated value. The temperature coefficient of reactivity is $+4.5 \times 10^{-5}$ ($\Delta k/k$) in the range from 25 to 40°C and is -1.25×10^{-5} ($\Delta k/k$) from 40 to 50°C. The temperature coefficient remained negative through 60°C, but an accurate measurement was not obtained at that point. The mean core temperature should lie in the range from 40 to 60°C.

The reactivity worth of one control plate as a function of its distance from the fuel was measured, and, although the shape of the experimental curve was in excellent agreement with the shape of the calculated curve, the over-all worth was lower by approximately 25%. Since less than the calculated excess reactivity will be required to compensate for the temperature coefficient of reactivity, the present control grids should still be adequate. Experiments are continuing on the reactivity effect of voids in the internal reflector region. Most of the above-described criticality experiments will be repeated with configurations which include the lead-boral reflector region.

The second set of screens used to redistribute the flow in the annular fuel elements has eliminated all reverse flow between the fuel plates. Further adjustments are being made to optimize the distribution

[redacted]

between the fuel plates and to eliminate eddies in the annulus between the fuel plate and the lead shield.

Modifications to the hydraulic flow test unit were completed, and all components necessary to measure the flow velocities in the fuel plates in the central cylinder, except the ionization chamber guide assembly, are on hand. Welding of the tubes in the guide assembly is under way.

Results of the first calculation to determine the extent of the after-heat problem indicate that no problem exists after 5-Mw operation, even with loss of cooling water flow, if one-third of the water remains in the core and covers the fuel plates. (A method has been devised to rotate the reactor and shield to the vertical position in case of power failure to ensure that the core will be under water.) Even though complete loss of water is considered an improbable event, this condition was examined as a limiting case. The initial calculations, for which only conductive cooling of the fuel after 5-Mw operation was assumed, showed that loss of water from the core would raise the fuel temperature so close to the melting temperature that there would be no assurance that some fuel plates had not melted. Other heat transfer mechanisms are now being taken into account to obtain a more accurate calculation.

The 1/4-in.-thick aluminum hemispheres which are to be used as the inner shell of the lead-boral shield were delivered, and they were found to meet the specifications. Flanges are being welded to the lower hemisphere before the surface is treated for bonding with the lead. The upper 1/8-in.-thick hemispherical sections are assembled and ready to be electroplated for lead bonding. Tanks were set up and solutions prepared for the electroplating. The assembly of the central cylinder is completed and final machining of the flange faces is under way. The first set of shim and control grids was completed.

Bulk Shielding Facility (BSF) Experiments

When the samples used in the GE heating experiment with laminated shield mockups (report ORNL-2488, p 4) were opened it was discovered that oil had leaked into the sample containers, and the entire series of tests is now being repeated with new samples. Thus far, the heating in samples in the forward positions (toward the reactor) has been measured in all the configurations: Be-Pb-LiH; Be-Fe-LiH; and Be-Mallory 1000-LiH. In addition, the heating in the samples in the aft positions of the Be-Pb-LiH configuration was measured. Fast-neutron and gamma-ray dose rates were measured at the interfaces of all the slabs and thermal-neutron flux values were estimated at selected locations near the LiH.

Data analysis and auxiliary experiments continue on the program to measure the spectrum of the prompt gamma rays from U^{235} fission. Methods were developed for correcting data for nonlinearity of the pulse-height analyzer, for combining pulse-height spectra from many runs having slightly different parameters, and for analyzing daily performance data of the spectrometer. These methods are needed because the results from about 80 full days of data collection must be combined properly into a single gamma-ray spectrum.

Tower Shielding Facility (TSF) Experiments

The investigation of the source of the gamma rays observed in a crew compartment 64 ft from a heavily gamma-ray-shielded reactor was continued with gamma-ray spectral measurements being made in the center of a compartmentalized detector shield constructed entirely of wood. Two 12-in.-thick water-filled compartments are on the sides, top, front, and rear of the detector shield. The TSR-I in the GE No. 1 reactor shield is used for the source in this investigation. The spectra observed in the shield are being compared with similar measurements made earlier in the ORNL cylindrical compartmentalized detector tank fabricated from aluminum. The comparison should indicate the importance of the contribution to the total dose rate by the aluminum capture gamma rays.

Lid Tank Shielding Facility (LTSF) Experiments

Thermal-neutron flux measurements were made in oil and water in a plane parallel to the LTSF source plate to obtain data needed in calculations of capture gamma-ray production in oil and water. The flux measured adjacent to the source plate is essentially symmetrical about the source axis.

As a check upon recent calculations, the thermal-neutron flux along the source plate centerline was also remeasured. It was found that the measured shape of the flux curve differs from that previously reported out to approximately 15 cm from the source plate and is in excellent agreement with the calculated shape.

In view of the large number of gold foil measurements made at the LTSF and their importance as a reference for all thermal-neutron measurements made here, it was decided to experimentally check the calculated value of the flux depression in water caused by these foils. While the experiment is not yet complete, it appears that the result will be in good agreement with the calculated value. The calculated value is 11%, and the preliminary experimental value is 13.4%. There also seems to be no large change in the flux depression factor with distance from the source plate, as was observed with indium foils.

A configuration consisting of approximately 3 in. of iron followed by water was investigated. Fast-neutron and gamma-ray dose rates and thermal-neutron fluxes were measured in the water beyond the iron on the source plate centerline. Gold foils were exposed through the iron at about 1/2-in. intervals. The data will be compared with British results and with "Cornpone" code calculations.

Oxidation Studies of Columbium

Studies of the rate of reaction between columbium and very low-pressure oxygen were continued. The results of two tests at an oxygen pressure of 1×10^{-4} mm Hg at 1000°C indicate that a linear relationship between weight gain and time exists under these conditions, at least up to an exposure of 325 min and a 1.5% weight gain. No deviations were noted in the reaction rate as the solubility limit of oxygen in columbium was exceeded. Although no oxide films were observed on the metal after these tests, the samples had a frosty appearance and were slightly roughened. Comparison of these results with those of tests at 1000°C and a 5×10^{-4} mm Hg oxygen pressure indicate an increase by about a factor of 3 in the reaction rate at the higher pressure. In addition, a black tenacious oxide film was observed on the surfaces of the samples after the tests at the higher pressure.

The microstructures and hardnesses of four columbium-oxygen alloys containing between 0.1 and 0.5% oxygen were determined following a 350-hr aging heat treatment at 540°C. The oxide precipitated as very fine particles which could be resolved at a magnification of 2000 diameters. No significant differences were noted in the microstructures of the samples containing the various amounts of oxygen. The relationship between hardness and oxygen content was very nearly linear in the range covered by these samples. The hardness varied from 166 VHN for the alloy containing 0.124% oxygen to 370 VHN for the alloy with 0.453% oxygen.

Fabrication of Columbium Alloys

Alloys of columbium with small percentages of cerium, beryllium, zirconium, and yttrium were prepared as 100-g arc melts and were rolled to 1/16-in.-thick strip to provide specimens for corrosion evaluation in molten lithium. The alloying elements were selected on the basis of the thermodynamic stability of their oxides relative to lithium oxide. It is hoped that these elements will "neutralize" the oxygen present in the niobium and thereby alleviate the corrosion problem. All the specimens were prepared by cold rolling. In general, beryllium additions of as little as 0.25% and zirconium additions of greater than 1% render the alloys subject to cracking even at low total reductions. The cracking tendency increases with increasing concentrations of these elements. The cerium and yttrium alloys were more easily fabricable.

Corrosion Resistance of Type 316 Stainless Steel to Contaminated Lithium

Duplicate room-temperature tensile tests were performed on type 316 stainless steel specimens (0.05 in. in thickness) which were subjected to one of the following environments at 1500°F for 100 hr prior to the tensile test: (1) argon (standard specimens), (2) pure lithium (0.0025% N_2, 0.0135% O_2), (3) lithium containing 2% lithium nitride, and (4) lithium containing 2% lithium oxide. The results of the tensile tests indicated that exposure to relatively pure lithium or to lithium containing a considerable amount of lithium oxide had no significant effect on tensile strength or elongation in comparison with exposure to argon.

Specimens exposed to lithium containing 2% lithium nitride were attacked along the grain boundaries to a depth of 7 mils. This attack resulted in a decrease in tensile strength of ~10% (98,555 psi vs 88,908 psi) and a 40% decrease in the elongation (31.5% vs 19.2%) in comparison with the standard specimens which were exposed to argon.

The specimens exposed to lithium plus lithium nitride were slightly ferromagnetic. No ferromagnetism could be detected in the standard specimens, the specimens exposed to pure lithium, or the specimens exposed to lithium plus lithium oxide.

Brazing Alloys for Service in Lithium

A number of alloys suitable for brazing in the 1100 to 1200°C temperature range were studied. Those exhibiting good flow on Zr, Ti, Mo, and Cb T-joints include 47 wt % Ti-47 wt % Zr-3 wt % V-3 wt % Be, 48 wt % Ti-49 wt % Zr-3 wt % Be, 45 wt % Ti-45 wt % Zr-10 wt % Fe, 74 wt % Zr-18 wt % Cb-8 wt % Be, and 80 wt % Zr-12 wt % Fe-8 wt % Be.

No attack was observed on 50 wt % Ti-50 wt % Zr and 70 wt % Ti-30 wt % V brazing-alloy buttons tested for 500 hr at 1700°F in lithium, and a 97 wt % Ti-3 wt % Be alloy tested at 1600°F for the same time showed only slight attack (1.5 mils). A 69 wt % Ti-31 wt % Fe alloy specimen was severely cracked under similar conditions. A spectrographic analysis of the titanium capsules used in these tests showed no dissimilar metal transfer from the brazing alloys to the titanium, except in the case of the test of the 97 wt % Ti-3 wt % Be alloy in which a "possible trace" of beryllium was detected in the titanium capsule wall.

Columbium and molybdenum T-joints brazed with 84 wt % Zr-16 wt % Fe, 69 wt % Ti-31 wt % Fe, and 72 wt % Ti-28 wt % Co were tested for 500 hr in static lithium. The first alloy was tested at 1600°F and the latter two at 1700°F. Metallographic examination and weight change data indicate good corrosion resistance, but these alloys are all brittle.

Spectrographic analyses were made on the walls of columbium capsules used in lithium corrosion tests of zirconium-base brazing alloys containing beryllium. Visual examination of these capsules had revealed dull, yellowish areas in the bath zones, and microspark analyses of the yellowish areas had shown the presence of zirconium. The spectrographic analyses showed strong beryllium lines in addition to the zirconium lines.

Yttrium Preparation

Large pieces of yttrium-magnesium alloy were successfully vacuum distilled by properly controlling the heating rate and time at temperature. The yttrium appeared to be quite dense and suitable for arc melting without compaction. Two reduction experiments indicated that it will be possible to cast the alloy into pieces about 1 in. square and 20 in. long. Although further work is needed to optimize the mold designs and pouring conditions, it now appears to be possible to process the alloy directly into consumable electrodes for arc melting without crushing and subsequent cold pressing.

Creep Buckling of Shells With Double Curvature

Experimental studies are being carried out at the Syracuse University Research Institute to determine the creep-buckling behavior of copper hemispherical shells under external pressure loadings at temperatures of 300 to 400°F. The results of the test program have shown that shells which are made to fail instantaneously, or within a relatively short time, collapse in a highly unsymmetrical shape. The buckling initiates at regions near the supported edge because of localized bending stresses.

On the other hand, shells which fail after being subjected to sustained loadings for long periods of time collapse much more symmetrically. The results for long periods imply that the bending stresses near the support or edge of the shell are reduced by creep effects until they no longer influence the buckled shape. Hence, the eventual failure becomes more symmetrical. If this phenomenon is verified, problems connected with analyses of creep buckling will be simplified.

[redacted]

C-85 Reactors - Aircraft
Nuclear Propulsion Systems

ORNL-2665

DISTRIBUTION

Oak Ridge Operations Office

1-10. Research and Development Division (Attn: H. M. [illegible]th)
11. Technical Information Service Extension

External

12. Atomic Energy Commission, [illegible]shington
13. Lockland Aircraft Reactor [illegible]ration Office
14. Hartford Area Office
15. Wright Air Development Cente[illegible] (Attn: Mat[illegible]ials Laboratory, SCORTO)
16. Wright Air Development Cente[illegible] (Attn: Po[illegible]r Plant Laboratory, WCLPW)
17. General Electric Company (AN[illegible])
18. Pratt & Whitney Aircraft Divi[illegible]n (CA[illegible])
19. ANP Project Office, Convair, [illegible]t Wor[illegible]
20. AFPR, Lockheed, Marietta
21. Los Alamos Scientific Laborator[illegible]
22. University of California Radiati[illegible]aboratory, Livermore

Internal

23. D. S. Billington
24. E. P. Blizard
25. A. L. Boch
26. G. E. Boyd
27. C. E. Center
28. R. A. Charpie
29. C. E. Clifford
30. A. P. Fraas
31. J. H. Frye
32. B. L. Greenstreet
33. W. R. Grimes
34. E. Guth
35. T. Hikido
36. C. S. Harrill
37. H. W. Hoffman
38. G. W. Keilholtz
39. F. C. Maienschein
40. W. D. Manly
41. H. J. Metz
42. A. J. Miller
43. E. J. Murphy
44. G. J. Nessle
45. H. W. Savage
46. A. W. Savolainen
47. W. H Sullivan
48. J. A. Swartout
49. E. H. Taylor
50. A. M. Weinberg
51. J. C. White
52. C. E. Winters
53. W. Zobel
54-55. [illegible]Laboratory Records
56-57. [illegible]entral Research Library
58. [illegible]RNL Y-12 Technical Library
[illegible]ocument Reference Section

[redacted]